Reply

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1 February 1983

Whiteman (1982) summarized wind and temperature structure features observed during temperature inversion breakup in deep valleys and formulated a hypothesis to account for these features. The hypothesis relied on energy budget and mass continuity arguments, stressing the role of convective boundary layer growth and upslope flows in producing the observed wind and temperature structure. One of the prominent features in the observations was the descent of the top of the temperature inversion after sunrise, hypothesized to be a consequence of mass continuity, whereby air removed from the base of the stable core in upslope flows results in subsidence of the entire stable core.

Fransioli (1983) suggests an additional mechanism to account for inversion descent, one previously suggested by Davidson and Rao (1958) and, more recently, by Lenschow *et al.* (1979). This mechanism calls for shear-induced turbulence to erode the top of the stable core by turbulent entrainment into the overlying flow. It should be clear that this mechanism is not an alternative to Whiteman's (1982) hypothesis of temperature inversion breakup since it deals only with the descent of the inversion top and does not provide alternate explanations of other observed features of wind and temperature structure evolution.

During the course of the research I considered, but rejected, the hypothesis that turbulent erosion played a significant role in inversion destruction under the weak synoptic flow conditions that were investigated. The observations that led me to this conclusion include:

1) Inversion descent occurred in a normal manner on days when the wind shear was very weak. Fig. 10 (Whiteman, 1982) presents a case of inversion descent where winds above the inversion were less than 1 m s^{-1}.

2) Observations in the Eagle Valley showed nearly identical inversion descent rates on different days when the wind shear varied within wide limits. For example, on the four days plotted in Fig. 7c (Whiteman, 1982), shear in a 50 m layer above the inversion at a time midway through the inversion breakup period varied from 0 to 0.07 s^{-1} (Whiteman, 1980; Figs. 17 and 95–97).

3) Valley inversion descent occurred regularly over a set period of time following sunrise. A limited number of observations made during the nighttime period (sunset to sunrise) found no cases of inversion descent during nighttime, when shears similar to those observed after sunrise were present above the inversion top. Acceptance of the erosion hypothesis therefore requires an explanation for the mechanism's improved efficiency or effect after sunrise. Davidson and Rao's hypothesis had such a corollary. They suggested that the post-sunrise growth of boundary layers over the ridgetops brought down stronger winds from the free atmosphere above. In my Colorado observations, however, I could find no evidence (Table 3; Whiteman, 1982) that the strength or direction of the prevailing synoptic winds influenced inversion destruction. In fact, for the weak synoptic flows investigated, I concluded that the effect of the topography was to isolate the temperature inversions from upper level flows, thereby producing more consistent temperature inversion evolution night after night.

4) Potential temperature jumps were not generally observed at the top of the stable core. Turbulent erosion should produce such jumps, which should increase in size as erosion progresses.

The turbulent erosion mechanism may prove important when winds above the inversion are stronger than I observed or in valleys where temperature inversions are weaker. Numerical modeling, fluid modeling, or further observational investigations could all be brought to bear on this question. If foehn conditions in the lee of the Rockies are a useful analogy, however, it would appear that winds must be rather strong before turbulent erosion becomes an important mechanism. There, arctic highs produce ground-based temperature inversions east of the Rockies. Cases have been documented where strong down-

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[1] Operated for the U.S. Department of Energy by Battelle Memorial Institute.

slope winds persist above the inversion top but are unable to penetrate to the ground.

Fransioli correctly states that the air pollution consequences of the two inversion descent hypotheses differ. Erosion will remove pollutants out of the top of the stable core and will disperse them into flows above the valley. Sinking of the stable core due to mass continuity will carry stable core pollutants deeper into the valley where they may be fumigated in convective boundary layers that develop over heated valley surfaces.

Fransioli, in his last paragraph, has generalized the conclusions of my paper and applied them to conditions outside the scope of my research. I must again restate the experimental design. Observations were made in all seasons in periods of clear weather when winds aloft were generally weak. Under such conditions when snow cover was not present, the temperature inversions in a valley developed regularly and showed little dependence on season or on the weak upper level winds. I have tried, in the paper, to indicate on the basis of limited observations, how temperature inversion evolution will vary with changes in soil moisture, snow cover, stronger winds aloft and other factors. The paper's conclusions, however, apply only to a rather narrow set of synoptic conditions.

Acknowledgments. This work was supported by the U.S. Environmental Protection Agency through Interagency Agreement AD-89-F-097-0 with the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

REFERENCES

Davidson, B., and P. K. Rao, 1958: Preliminary report on valley wind studies in Vermont, 1957. Final Report, Contract AF 19(604)-1971, AFCRC-TR-58-29, College of Engineering, New York University, 54 pp.

Fransioli, P. M., 1983: Comments on "Breakup of temperature inversions in deep mountain valleys: Part I. Observations". *J. Climate Appl. Meteor.*, **22,** 1314.

Lenschow, D. H., B. B. Stankov and L. Mahrt, 1979: The rapid morning boundary layer transition. *J. Atmos. Sci.*, **36,** 2108–2124.

Whiteman, C. D., 1980: Breakup of temperature inversions in Colorado mountain valleys. Ph.D. dissertation, Colorado State University, 256 pp.; also Atmos. Sci. Pap. No. 328, Colorado State University.

——, 1982: Breakup of temperature inversions in deep mountain valleys: Part I. Observations. *J. Appl. Meteor.*, **21,** 270–289.